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(54) METHOD OF UTILIZING FLOWABLE DEVICES IN WELLBORES

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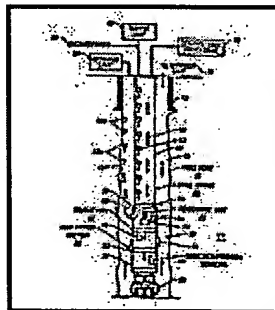
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(57) This invention relates to flowable devices and methods of utilizing such flowable devices in wellbores to provide communication between surface and downhole instruments, among downhole devices, establish a communication network in the wellbore, act as sensors, and act as power transfer devices. The flowable devices are adapted to move with a fluid flowing in the wellbore. The flowable device may be memory device or a device that can provide a measure of a parameter of interest or act as a power transfer device. The flowable devices are introduced into the flow of a fluid flowing in the wellbore. The fluid moves the device in the wellbore. If the device is a data exchange device, it may be channeled in a manner that enables a device in the wellbore to



interact with the memory device, which may include retrieving information from the flowable device and/or recording information on the flowable device. The sensor in a flowable device can take a variety of measurement(s) in the wellbore. The flowable devices return to the surface with the returning fluid.



Description Claims

METHOD OF DEVICES IN WELLBORES FLOWABLE [CROSS-REFERENCE] TO RELATED APPLICATIONS This application takes priority from United States Patent Application Serial Nos. [60/136,656] filed August [5, 1999,] and 60/147,127 filed May [28, 1999,] each assigned to the assignee of this application.

BACKGROUND [OF THE INVENTION] [1. FIELD] of the Invention This invention relates generally [TO OILFIELD WELLBORES] and more particularly to [WELLBORE] systems and methods for the use of flowable devices in such [WELLBORES.]

2. Background of the Art [HYDROCARBONS,] such as [OIL] and [GAS,] are trapped in [SUBSURFACE] formations.

Hydrocarbon-bearing formations are [USUALLY REFERRED] to as the producing zones or oil and gas reservoirs or "reservoirs." To obtain hydrocarbons from such formations, [WELLBORES OR BOREHOLES] are [DRILLED] from a surface location or "well site" on land or offshore into one or more such reservoirs. [A WELLBORE] is usually formed by drilling a borehole of a desired diameter or size by a drill bit conveyed from a [RIG] at the well site. The drill string includes a hollow tubing attached to a drilling assembly at its bottom end. The drilling assembly (also referred to herein as the "bottomhole assembly" or "BHA") includes the drill bit for drilling the wellbore and a number of sensors for determining a variety of [SUBSURFACE] or downhole parameters. The tubing usually is a continuous pipe made by joining relatively small sections (each section being 30-40 feet long) of rigid [META] ! IC pipe [(COMMONLY] referred to as the "drill pipe") or a relatively flexible but continuous tubing on a [REEL] (commonly referred to as the "coiled-tubing"). [WHEN] coiled tubing is used, the drill bit is rotated by a drilling motor in the [DRILLING ASSEMBLY_ MUD MOTORS] are most commonly utilized as [DRILLING MOTORS. WHEN] a drill pipe is used as the tubing, the drill bit is rotated by rotating the drill pipe at the surface and/or by the mud motor. During drilling of a [WELLBORE, DRILLING FLUID (COMMONLY] referred to as the "mud") is supplied under pressure from a source thereof at the [SURFACE ! THROUGH] the drilling tubing. The mud passes through the [DRILLING] assembly, rotates the drilling motor, if used, and [DISCHARGES] at the drill bit bottom. The mud discharged at the drill bit bottom returns to the surface via the spacing between the drill string and the wellbore (also referred to herein as the "annulus") carrying the rock pieces (referred to in the art as the "cuttings") therewith.

Most of the currently utilized drilling assemblies include a variety of devices and sensors to monitor and [CONTROL] the [DRIVING] process and to obtain valuable information about the rock, [WELLBORE] conditions, and the matrix surrounding the drilling assembly. The devices and sensors used in a particular drilling assembly depend upon the [SPECIFIC] [REQUIREMENTS] of the well being [DRILLED.] Such devices include mud motors, adjustable [STABILIZERS] [TO] provide [LATERAL] stability to the drilling assembly, adjustable bends, adjustable force application devices to maintain and to alter the drilling direction, and thrusters to apply desired amount of force on the drill bit. The drilling assembly may include sensors for determining (a) [DRILLING] parameters, such as the fluid flow rate, rotational speed (r. p. m.) of the drill bit and/or mud motor, the weight on bit [("WOB"),] and torque of the bit; (b) borehole parameters, such as temperature, pressure, hole size and shape, and [CHEMICAL] and physical properties of the circulating fluid,

inclination, azimuth, etc., (c) drilling assembly parameters, such as [DIFFERENTIAL] pressure across the mud motor or BHA, vibration, bending, stick-slip, whirl; and (d) formation parameters, such as formation resistivity, dielectric constant, porosity, density, [PERMEABILITY,] acoustic velocity, natural gamma ray, formation pressure, fluid mobility, fluid composition, and composition of the rock matrix.

During drilling, there is ongoing need to adjust the various devices in the drill string. Frequently, signals and data are transmitted from surface control units to the drilling assembly. Data and the sensor [RESULTS] from the drilling assembly are communicated to the surface. Commonly utilized telemetry systems, such as mud pulse telemetry and acoustic telemetry systems, are relatively low data rate transfer systems. Consequently, large amounts of [DOWNHOLE] measured and computed information about the various above-noted parameters is stored in memory in the drilling assembly for later use. [ALSO,] relatively few instructions and data can be transmitted from the surface to the drilling assembly during the drilling operations.

After the well has been drilled, the well may be completed, i. e., made ready for production. The completion of the [WELLBORE] requires a variety of operations, such as setting a casing, cementing, setting packers, operating flow control devices, and perforating. There is need to send signals and data from the surface during such completion operations and to receive information about certain downhole parameters. This information may be required to monitor status and/or for the operation of devices in the wellbore ("downhole devices"), to actuate devices to perform a task or operation or to gather data about the subsurface wellbore completion system, information about produced or injected fluids or information about surrounding formation. After the well has started to produce, there is a continuous need to take measurements of various [DOWNHOLE] parameters and to transmit [DOWNHOLE] [GENERATED] signals and data to the surface and to receive [DOWNHOLE] information transmitted from the surface.

The present invention provides systems and methods wherein discrete [FLOWABLE] devices are utilized to communicate [SURFACE-GENERATED] information (signals and data) to downhole devices, measure and record [DOWNHOLE] parameters of interest, and retrieve from downhole devices, and to make measurements relating to one or more parameters of interest relating to the wellbore systems.

SUMMARY OF THE INVENTION This invention provides a method of [UTILIZING] [FLOWABLE] devices to communicate between surface and [DOWNHOLE] instruments and to measure [DOWNHOLE] parameters of interest. In one method, one or more flowable devices are introduced into fluid flowing in the wellbore. The flowable device is a data carrier, which may be a memory device, a measurement device that can make one or more measurements of a parameter of interest, such as temperature, pressure and flow rate, and a device with a [CHEMICAL] or biological base that provides some useful information about a [DOWNHOLE] parameter or a device that can transfer power to another device.

In one aspect of the invention, memory-type flowable devices are sent [DOWNHOLE] wherein a device in the [WELLBORE] reads stored information from the flowable devices and/or writes information on the [FLOWABLE DEVICE]. IF the [FLOWABLE] device is a measurement device, it takes the measurement, such as temperature, pressure, flow rate, etc., at one or more locations in the wellbore. The flowable devices flow back to the surface with the fluid, where they are retrieved. The data in the [FLOWABLE] devices [AND/OR] the measurement information obtained by the flowable devices is retrieved for use and

[ANALYSIS] During drilling of a [WELLBORE,] the [FLOWABLE] devices may be introduced into the drilling fluid pumped into the drill string. A data exchange device in the drill string reads information from the [FLOWABLE] devices [AND/OR] writes information on the flowable devices. An inductive [COUPLING] device may be utilized for reading information from or writing information on the [FLOWABLE] devices. A [DOWNHOLE] [CONTROLLER CONTROLS] the information flow between the [FLOWABLE] device and other [DOWNHOLE] devices and sensors. The [FLOWABLE] devices return to the surface with the circulating drilling fluid and are retrieved. Each [FLOWABLE] device may be assigned an address for identification. Redundant devices may be utilized.

In a production well, the flowable devices may be pumped [DOWNHOLE] via a tubing that runs from a surface location to a desired depth in the wellbore and then returns to the surface. A U-shaped tubing may be utilized for this purpose. The [FLOWABLE] devices may also be carried [DOWNHOLE] via a single tubing or stored in a container or magazine located or placed at a suitable location downhole, from which location the [FLOWABLE] devices are released into the flow of the produced fluid, which carries the flowable devices to the surface. The release or disposal from the magazine may be done periodically, upon command, or upon the occurrence of one or more events. The magazine may be recharged by intervention into the wellbore.

The tubing that carries the [FLOWABLE DEVICES MAY] be [SPECIFICALLY] made to convey the flowable devices or it may be a hydraulic line with [ADDITIONAL] functionality. The [FLOWABLE] devices may retrieve information from downhole devices [AND/OR] make measurements along the [WELLBORE.] A [PLURALITY OF FLOWABLE] devices may be present in a [WELLBORE] at any given time, some of which may be designed to communicate with other [FLOWABLE] device or other downhole device, thereby providing a communication network in the wellbore. The [FLOWABLE] devices may be intentionally implanted in the wellbore wall to form a communication [LINK] or network in the wellbore. A device in the wellbore reads the information carried by the [FLOWABLE] devices and provides such information to a [DOWNHOLE] [CONTROLLER] for use. The information sent [DOWNHOLE] may contain commands for the downhole controller to perform a particular operation, such as operating a [DEVICE THE DOWNHOLE CONTROLLER] may also send information back to the surface by writing information on the flowable devices. This may be information from a [DOWNHOLE] system or confirmation of the receipt of the information from surface.

Examples of the more important features of the invention have been summarized rather [BROADLY] in order that the detailed description thereof that follows may be better [UNDERSTOOD,] and in order that the contributions to the art maybe appreciated. There are, of course, additional features of the invention that will be described [HEREINAFTER] and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION [OF] THE [DRAWINGS] For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like [ELEMENTS] have been given like numerals, wherein: Figure 1 is a schematic illustration of a drill string in a wellbore during drilling of a [WELLBORE,] wherein [FLOWABLE] devices are pumped [DOWNHOLE] with the drilling fluid Figure 2 is a schematic illustration of a [WELLBORE] during drilling wherein flowable devices are implanted in the borehole wall to form a communications line in the open hole section and wherein a cable is used for communication in the cased hole section.

Figure 3 is a schematic illustration of a [WELLBORE] wherein [FLOWABLE] devices are pumped [DOWNHOLE] and retrieved to the surface via [A U-SHAPED HYDRAULIC OR FLUID] line disposed in the wellbore.

Figure 4 is a schematic illustration of a production well wherein flowable devices are released in the flow of the produced fluid at a suitable location.

Figure 5 is a schematic illustration of a multi-lateral production [WELLBORE] wherein [FLOWABLE] devices are pumped down through a hydraulic line and released into the fluid flow of the first lateral and where information is communicated from the first lateral to the second lateral through the earth formation and wherein flowable devices may also be released into the fluid flow of the second lateral to carry such devices to the surface.

Figure 6 is a block functional diagram of a [FLOWABLE] device according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED [EMBODIMENT] The present invention utilizes "flowable devices" in [WELLBORES] to perform one or more functions downhole. For the purpose of this disclosure, a flowable device means a discrete device which is adapted to be moved at [LEAST] in part, by a fluid flowing in the wellbore. The [FLOWABLE] device according to this invention is [PREFERABLY] of relatively small size (generally in the few [MILLIMETERS] to a centimeter range in outer dimensions) that can perform a useful function in the [WELLBORE.] Such a device may make measurements downhole, sense a [DOWNHOLE] parameter, exchange data with a [DOWNHOLE] device, store information therein, [AND/OR] store power. The [FLOWABLE] device may communicate data and signals with other flowable devices and/or devices placed in the wellbore ("downhole devices"). The flowable device may be programmed or coded with desired information. An important feature of the [FLOWABLE] devices of the present invention is that they are sufficiently small in size so that they can circulate with the drilling fluid without impairing the [DRILLING OPERATIONS.]

Such devices [PREFERABLY] can flow with a variety of fluids in the [WELLBORE. IN ANOTHER] aspect of the invention, the devices may be installed in the wellbore wall either permanently or [TEMPORARILY] to form a network of devices for providing selected measurement of one or more downhole parameters. The various aspects of the present invention are described below in reference to Figures 1-6 utilizing exemplary wellbores.

In a preferred embodiment, the [FLOWABLE] device may include a sensor for providing measurements relating to one or more parameters of interest, a memory for storing data [AND/OR] instructions, an antenna for transmitting [AND/OR] receiving signals from other devices [AND/OR] [FLOWABLE] devices in the wellbore and a [CONTROL] circuit or [CONTROLLER] for processing, at least in part, sensor measurements and for controlling the transmission of data from the device, and for processing data received from the device. The device may include a battery for [SUPPLYING] power to its various components-The device may also include a power generation device due to the turbulence in the [WELLBORE FLUID FLOW.] The generated power may be utilized to charge the battery in the device.

Figure 1 is an illustration of the use of flowable devices during drilling of a [WELLBORE,] which shows a wellbore 10 being [DRILLED] by a drill string 20 from a surface location [11.] A casing 12 is placed at an upper section of the wellbore 10 to prevent collapsing of the wellbore 10 near the surface 11. The drilling string 20 [INCLUDES] a tubing 22, which

may be a drill pipe made from joining smaller sections of [RIGID] pipe or a coiled tubing, and a [DRILLING] assembly 30 [(ALSO) referred to as a bottom hole assembly (OR "BHA")] attached to the bottom end 24 of the tubing 22.

The drilling assembly 30 carries a drill bit 26, which is rotated to [DISINTEGRATE] the rock formation. Any suitable drilling assembly may be utilized for the purpose of this invention. [COMMONLY] used drilling assemblies include a variety of devices and sensors. The drilling assembly 30 is shown to include a mud motor section 32 that [INCLUDES] a power section 33 and a [BEARING] assembly section 34. To drill the [WELLBORE] 10, drilling fluid 60 from a source 62 is supplied under pressure to the tubing 22. The drilling fluid 60 causes the mud motor 32 to rotate, which rotates the drill bit 26. The bearing assembly section 34 [INCLUDES] bearings to provide lateral and axial stability to a drill shaft (not shown) that couples the power section 33 of the mud motor 32 to the drill bit [26 THE DRILLING] assembly 30 contains a plurality of direction and position sensor 42 for determining the position (x, y and z coordinates) with respect to a known point and inclination of the drilling assembly 30 during [DRILLING] of the wellbore 10. The sensors 42 may include, accelerometers, inclinometers, magnetometers, and navigational devices. The drilling [ASSEMBLY] further [INCLUDES] a variety of sensors denoted herein by numeral 43 for providing information about the [BOREHOLE] parameters, drilling parameters and drilling assembly condition parameters, such as pressure, temperature, fluid flow rate, [DIFFERENTIAL] pressure across the mud motor, equivalent [CIRCULATORY DENSITY] of the drilling fluid, drill bit [AND/OR] mud motor rotational speed, vibration, weight on bit, etc.

Formation evaluation sensors 40 (also referred to as the "FE" sensors) are [INCLUDED] in the drilling assembly 30 to determine properties of the formations 77 surrounding the wellbore 10. The FE sensors typically include resistivity ; acoustic, [NUCLEAR] and [NUCLEAR] magnetic resonance sensors which alone [PROVIDED] measurements that are used alone or in combination of measurements from other sensors to calculate, among other things, formation resistivity, water saturation, dielectric constant, porosity, permeability, pressure, density, and other properties or characteristics of the formation [77. A TWO-WAY] telemetry unit 44 communicates [DATA/SIGNALS] between the drilling assembly 30 and a surface [CONTROL] unit or processor 70, which usually [INCLUDES] a computer and associated equipment.

During drilling, according to one aspect of the [PRESENT INVENTION, FLOWABLE] devices 63 are introduced at one or more suitable locations into the flow of the drilling fluid 60. The [FLOWABLE] devices 63 travel with the fluid 60 down to the BHA 30 (forward [FLOW] ,] wherein they are [CHANNELED] into a passage 69. A data exchange device 72, usually a [READ/WRITE] device disposed adjacent to or in the passage 69, which can read information stored in the devices 63 (at the surface or obtained during flow) and can write on the devices 63 any information that needs to be sent back to the surface 11. An inductive [COUPLING] unit or another suitable device may be used as a read/write device 72. Each [FLOWABLE] device 63 may be programmed at the surface with a unique address and specific or predetermined information. Such information may include instructions for the [CONTROLLER] 73 or other electronic circuits to perform a selected function, such as activate ribs 74 of a force application unit to change drilling direction or the information may include signals for the controller 73 to transmit values of certain downhole measured parameters or take another action. The controller 73 may include a [MICROPROCESSOR-BASED] circuit that causes the [READ/WRITE] unit 72 to exchange appropriate information with the flowable devices 63. The controller 73 process downhole the

information received from the flowable devices 63 and also provides information to the devices 63 that is to be carried to the surface. The read/write device 72 may write data that has been gathered [DOWNHOLE] on the [FLOWABLE] devices 63 leaving the passage 69. The devices 63 may also be measurement or sensing devices, in that, they may provide measurements of certain parameters of interest such as pressure, temperature, flow rate, viscosity, composition of the fluid, presence of a particular [CHEMICAL,] water saturation, composition, corrosion, vibration, etc. The devices 63 return to the surface 11 with the fluid circulating through the annulus 13 between the [WELLBORE] 10 and drill string 22.

The [FLOWABLE] devices returning to the surface designated herein for [CONVENIENCE] by numeral 63a are received at the surface by a recovery unit 64. The returning devices 63a may be recovered by [FILTERING] [MAGNETIC] force or other techniques. The information contained in the returning devices 63a is retrieved, interpreted and used as appropriate. Thus, in the drilling mode, the [FLOWABLE] devices 63 [FLOW DOWNHOLE] where they perform an intended function, which may be taking measurements of a parameter of interest or providing information to a downhole controller 73 or retrieving information from a [DOWNHOLE] device. The devices 63a return to the surface (the return destination) via the [ANNULUS] 13.

During [DRILLING,] some of the devices may be lost in the flow process or get attached or stuck to the wall of the wellbore 10. Redundant devices may be supplied to account for such loss. Once the [CONTROLLER] 73 has communicated with a device having a particular address, it may be programmed to ignore the redundant device. Alternatively, the [CONTROLLER] 73 may cause a signal to be sent to the surface confirming receipt of each address. If a particular address is not received by the downhole device 72, a duplicate device may be sent. The devices 63a that get attached to the wellbore wall [10A] (see Figure 2), may act as sensors or communication locations in the [WELLBORE] 10. A stuck device may communicate with another [FLOWABLE] device stuck along the wall 10a or with devices [PASSING] adjacent the stuck device, thereby forming a communications network. The returning devices 63a can retrieve information from the devices stuck in the well 10. Thus, the [FLOWABLE] devices in one aspect, may form a virtual network of devices which can pass data/information to the surface. [ALTERNATIVELY,] some of the devices 63 may be adapted or designed to [LODGE] against or deposited on the [WELLBORE WALL 10A, THEREBY] providing permanent sensors and/or communication devices in the [WELLBORE] 10. In one embodiment, the flowable devices may be designed to be deposited on the [BOREHOLE] wall during the drilling process. As one flowable device can communicate with another neighboring [FLOWABLE] device, a plurality of flowable devices deposited on the [WELLBORE] [WALL] may form a communications network. As drilling of new formation continues new [FLOWABLE] devices are constantly deposited on the [BOREHOLE] wall to maintain the network. When drilling [OF THE] section is completed, the [FLOWABLE] devices may be retrieved from the [BOREHOLE] [WALL] for use in another application. The devices 63 may include a movable element that can generate power due to turbulence in the wellbore fluid, which power can be used to charge a resident battery in the [FLOWABLE] devices. [FURTHER,] the devices 63 may include a propulsion mechanism (as more [FULLY] explained in reference to Figure 6) that aids these devices in flowing with or in the fluid 60. The devices 63 [USUALLY] are autonomous devices and may include a dynamic ballast that can aid such devices to flow in the fluid 60.

Flowable devices may also be periodically planted in the wellbore wall in a [CONTROLLED] operation to form a communication line [ALONG] the [WELLBORE,] as opposed to randomly depositing flowable devices using the hydraulic pressure of the

[DRILLING] fluid. An apparatus may be constructed as part of the [DOWNHOLE] assembly to mechanically apply a force to press or screw the [FLOWABLE] device into the [WELLBORE] [WALL.] In this operation, the force required to implant the device may be measured, either by sensors within the flowable device itself or sensors within the implanting apparatus. This measured parameter may be communicated to the surface and used to investigate and monitor rock mechanical properties. The [FLOWABLE] devices may be pumped downhole to the planting apparatus, or kept in a magazine [DOWNHOLE] to be used by the planting apparatus. In this case the [FLOWABLE] devices may be permanently installed. Figure 2 which is a schematic illustration of a [WELLBORE,] wherein devices made in accordance with the present invention are implanted in the [BOREHOLE] wall during drilling of the [WELLBORE] 10 to form a communication network. Figure 2 shows a well 10 being [DRILLED] by drill bit 26 at the bottom of a [DRILLING] assembly 80 carried by a drilling tubing 81. [DRILLING] fluid 83 supplied under pressure through the tubing 81 discharges at the bottom of the drill bit 26. [FLOWABLE] devices 63 are introduced or pumped into the fluid 83 and captured or retrieved by a device 84 in the drilling assembly [80.] The drilling assembly 80 [INCLUDES] an implanting device 85 that implants the retrieved flowable devices 63 via a head 86 into the [BOREHOLE WALL 10A.] The devices which are implanted during the drilling of the [WELLBORE] 10 are denoted by [NUMERAL] 63b. The devices 63 may be pumped downhole through a dedicated tubing 71 placed in the [DRILLING] tubing 81.

[IF COILED TUBING] is used as the tubing 81, the tubing 71 for carrying the [FLOWABLE] devices 63 to the implanter 85 may be built inside or outside the coiled tubing.

Alternatively, the devices to be implanted may be stored in a chamber or magazine [83,] which [DELIVER] them to the implanter 85. The implanted flowable devices 63b in the well 10 can exchange data with each other [AND/OR] other [FLOWABLE] devices returning to the surface via the [ANNULUS] 13 [AND/OR] with other devices in the drill string as described above in reference to Figure 1. A communication device 88 may be disposed in the [WELL] at any suitable location, such as below the upper casing 12 to communicate with the implanted devices 63b. The communication device 88 may communicate with one or more nearby flowable devices 63b such as a device denoted by [NUMERAL] 63b, which device then communicates with next device and so forth down the line to the remaining implanted devices [63B SIMILARLY,] the implanted devices 63b communicate uphole up to the devices 63b which communicates with the device 88, thus establishing a two-way communication link or line along the wellbore 10. The device 88 can read data from and write data on the devices 63b. It is operatively coupled to a receiver/transmitter unit 87 and a processor 89 at the surface by a conductor or link 91. The link 91 may be an [ELECTRICAL] conduct or a fiber optic [LINK.] The processor 89 processes the data received by the [RECEIVER/TRANSMITTER] unit 87 from the devices 63b and [ALSO~SENDS] data to the devices 63b via the [RECEIVER/TRANSMITTER] 87. The implanted devices 63b may be used to take measurements for one or more selected [DOWNHOLE] parameters during and after the drilling of the wellbore 10.

Figure 3 illustrates an alternative method of transporting the devices 63 to a [DOWNHOLE] location. Figure 3 shows a wellbore 101 formed to a depth 102. For simplicity and ease of understanding, normal equipment and sensors placed in a [WELLBORE] are not shown. A fluid conduit [110] is disposed in the wellbore. The conduit 110 runs from a fluid supply unit 112, forms a U-return 111 and returns to [THE SURFACE 11. FLOWABLE] devices

63 are pumped into the conduit 110 by the supply unit [112] with a suitable fluid. A [DOWNHOLE] device 72a retrieves information from the [FLOWABLE] devices 63 passing through a channel 70a [AND/OR] writes information on such devices. A [CONTROLLER] 73a receives the information from the flowable devices 63 and utilizes it for the intended purpose. [CONTROLLER] 73a also controls the operation of the device 72a and thus can cause it to transfer the required information onto the [FLOWABLE] devices 63. The [FLOWABLE] devices 63 then return to the surface via the return segment 110a of the tubing 110. A retrieval unit 120 at the surface recovers the returning [FLOWABLE] devices 63a, which may be analyzed by a [CONTROLLER] 122 or by another method. The devices 63 may perform sensory and other functions described above in references to Figure 1.

Figure 4 is a schematic illustration of a production well 200 wherein [FLOWABLE] devices 209 are released into the produced fluid or formation fluid 204, which carries these devices to the surface. Figure 4 shows a well 201 that has an upper casing 203 and a well casing 202 installed therein. Formation fluid 204 [FLOWS] into the well 201 through perforations 207. The fluid 204 enters the wellbore and [FLOWS] to the surface via a production tubing 210. For simplicity and ease of understanding, Figure 4 [DOES] not show the; various production devices, such as flow control screens, valves and submersible pumps, [ETC-A PLURALITY] of [FLOWABLE] devices 209 are stored or disposed in a suitable container at a selected location 211 in the [WELLBORE] 201. The devices 209 are [SELECTIVELY] released into the flow of the produced fluid 204, which fluid carries these devices, the released devices are designated by numeral 209a to the surface. The devices 209a are retrieved by a retrieval unit 220 and [ANALYZED.] As noted above in reference to Figures 1 and 3, the [FLOWABLE] devices 209a may be sensor devices or information containing devices or [BOTH.] Periodic release of sensory devices can provide information about the downhole conditions. Thus, in this aspect of the invention, the [FLOWABLE] devices are released in the well 201 to transfer downhole information during the production phase of the [WELL] 201.

Communication in open-hole sections may be achieved using flowable devices in the drilling mud deposited on the borehole [WATT.] or by using implanted flowable devices as described above. In cased hole sections [OFTEN] found above open-hole sections, communications may be achieved in several ways; through [FLOWABLE] devices deposited in the mud filter cake or implanted in the [BOREHOLE] wall during the drilling process, or through [FLOWABLE] devices mixed in the cement which fills the [ANNULUS] between the [BOREHOLE] [WALL/MUD] [FILTER] cake and the casing, or through a communication channel installed as part of the casing. The latter may include a receiver [AT THE] bottom of the casing to pick up information from the devices, and a transmitter to send this information to the surface and vice versa.

The communication device associated with the casing could be an electrical or fibre-optic or other type of cable, an acoustic signal or an [ELECTROMAGNETIC] signal carried within the casing or within the earth, or other methods of communication. In conclusion, a communication system based on the use of [FLOWABLE] devices may be used in combination with other communication methods to cover different sections of the wellbore, or to communicate over distances not covered by a wellbore.

Another example of using [FLOWABLE] devices in combination with other communication systems is a multilateral well. One or more laterals of the well may have a two-way communication system with flowable devices, [WHILE] one or more laterals of the same well may not have a full two-way communication system with the flowable devices. In one

embodiment of the invention, the first lateral is equipped with a single tube or a U-tube that allows [FLOWABLE] devices containing information from surface to travel to the bottom of the first lateral. The second lateral is not equipped with a tubing, but has [FLOWABLE] devices stored in a [DOWNHOLE] magazine. A message to the second lateral is pumped into the first [LATERAL.] From the receiver station in the first lateral, information such as a command to release a [FLOWABLE] device in the second lateral, is transmitted from the first lateral to the second lateral through acoustic or [ELECTROMAGNETIC] signals through the earth. Upon receipt of this information in the second lateral, the required task, such as writing to and releasing a [FLOWABLE] device or initiating some action [DOWNHOLE] is performed. Provided the distance and formation characteristics allow transmission of signal through the earth formation, the same concept can be used to communicate between individual wellbores.

Figure 5 is an [EXEMPLARY] schematic illustration of an [MULTILATERAL] production well 300, wherein [FLOWABLE] devices are pumped into one branch or lateral and then utilized for communication between the laterals. Figure 5 shows a main well section [301] having two branch [WELLS OR LATERALS 301 A] and 301b. In the exemplary lateral [WELLBORE] configuration of Figure 5, both wells [301A] and [301B] are shown to be production wells Well 301a and [301 B PRODUCE FLUIDS] (hydrocarbons) which are shown by arrow 302a and 302b, respectively. Flowable devices 63 are pumped into the first [LATERAL] [301 A] via a tubing 310 from a [SUPPLY] unit 321 at the surface [11. THE] devices [63] are discharged at a known depth 303a where a receiver unit 370a retrieves data from the devices 63. The devices return to the surface with the produced fluid 302a. The returning devices from wellbore 301 are denoted by 63d.

A transmitter unit 380 transmits signals 371 in response to information retrieved from the [FLOWABLE] devices 63. A second receiver [370B] in the second lateral 301 b receives signals 371. A [CONTROLLER] unit or processor 382 utilizes the received signals to perform an intended function or operation, which may include operating a device downhole, such as a valve, a sliding sleeve, or a pump, etc. Flowable devices [63C] may be disposed in magazine 383 in the second lateral [301B] and released into the fluid flow 302b by the controller 382. The devices 63d and [63C] flowing uphole are retrieved at the surface by a receiver unit 320 and the data carried by the [FLOWABLE] devices [63C] and 63d is processed by the processor 322. It [SHOULD] be noted that Figure 5 is only one [EXAMPLE] of utilizing the [FLOWABLE] devices in multiple wellbores.

The wells selected for intercommunication may be [SEPARATE] wells in a field. The signals 371 may be received by instruments in one or more [WELLS AND/OR] at the surface for use in performing an intended task.

Figure 6 shows a [BLOCK FUNCTIONAL] diagram of a [FLOWABLE] device 450 according to one embodiment of the present invention. The device 450 is preferably [ENCAPSULATED] in a material 452 that is suitable for downhole environment such as ceramic, and includes one or more sensor [ELEMENTS] [454,] a control circuit or [CONTROLLER] 456 and a memory unit [458 A RESIDENT] power [SUPPLY] [460 SUPPLIES] power to the sensor 454, controller 456, memory 458 and any other electrical component of the device [450.] The [CONTROLLER] 456 may include a processor that interacts with one or more programs in the device to process the data gathered by the device and/or the measurements made by the device to compute, at [LEAST] partly, one or more parameters of interest, including results or answers. For example, the device 450 may [CALCULATE] a parameter, change its future function and/or transmit a signal in response

to the calculated parameter to cause an action by another [FLOWABLE] device or a device in the [WELLBORE. FOR EXAMPLE,] the device may determine a detrimental condition downhole, such as presence of water and then send a signal to a fluid flow control device in the [WELLBORE] to shut down a production zone or the well. The device may be designed to have sufficient intelligence and processing capability so it can take any number of different actions in the wellbore. A power generation unit that generates electrical power due to the turbulence in the flow may be incorporated in the device 450 to charge [A] battery (resident power supply) 460.

An antenna [462] is provided to transmit and/or receive signals, thereby providing one-way or two-way communication (as desired) between the flowable device [450] and another device, which may be a flowable device or a device [LOCATED] [DOWNHOLE] or at the surface. The device [450] may be programmed at the surface or [DOWNHOLE] to carry data and instructions. The surface information programmed into a [FLOWABLE] device is read by a device in the [WELLBORE] [WHILE] the [DOWNHOLE] programmed information may be read at the surface or by reading devices downhole. The device 450 may transmit and receive signals in the [WELLBORE] and thus communicate with other devices. Such a flowable device can transfer or exchange information with other devices, establish communication [LINK.] along the [WELLBORE,] provide two-way communication between surface and [DOWNHOLE] devices, or between different wellbores in a field or laterals of a wellbore system, and establish a communication network in the wellbore and/or between the surface instrumentation and [DOWNHOLE] devices-Each such device may be coded with an identification number or address, which can be utilized to [CONFIRM] the receipt or transfer of information by the devices deployed to receive the information from the [FLOWABLE] device [450.] In one method, the [FLOWABLE] device 450 may be sequentially numbered and introduced into the fluid flow to be received at a target location. If the receiving device receives a [FLOWABLE] device, it can cause a signal to be sent to the [SENDING LOCATION,] thereby confirming the arrival [OF] a particular device. If the receiving device does not confirm the [ARRIVAL] of a particular device, a second device carrying the same information and the address may be sent. This system will provide a closed [LOOP] system for [TRANSFERRING] information between locations.

In another aspect of the invention, the flowable device may contain a chemical that alters a state in response to a [DOWNHOLE] parameter, which provides a measure of a [DOWNHOLE] parameter. Other devices, such as devices that contain biological mass or mechanical devices that are designed to carry information or sense a parameters may also be utilized. In yet another aspect, the flowable device may be a device carrying power, which may be received by the receiving device.

Thus, specially designed flowable devices may be utilized to transfer power from one location to another, such as from the surface to a [DOWNHOLE] device.

The [FLOWABLE] device 450 may include a ballast 470 that can be released or activated to alter the buoyancy of the device 450. Any other method also may be utilized to make the device with variable buoyancy. Additionally, the device 450 may also include a propulsion mechanism 480 that can be selectively activated to aid the device 450 to flow within the fluid path. The propulsion mechanism may be [SELF-ACTIVATED] or activated by an event such as the location of the device 450 in the fluid or its speed.

While the foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all

- variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

Description Claims

WHAT IS CLAIMED IS: 1. A method of utilizing discrete devices in a [WELLBORE] wherein a working fluid provides fluid flow path for moving said discrete devices from a first location of introduction of said devices into the [FLOW PATH TO] a second location of interest, said method comprising: -selecting at [LEAST] one flowable discrete device constituting a data carrier that is adapted to be moved in the [WELLBORE] at [LEAST] in part by the working fluid ("flowable device"); introducing the at [LEAST] one [FLOWABLE] discrete device into the fluid flow path at the first location to cause the working fluid to move the at least one flowable device to the second location of interest; and -providing a data exchange device in the fluid flow path for effecting data exchange with the at least one flowable discrete device.

2. The method of claim 1, wherein selecting the at least one flowable device comprises selecting the at [LEAST] one [FLOWABLE] device from a group consisting [OF ;] (i) a device having a sensor for providing a measure of a parameter of interest ; (ii) a device having a memory for storing data therein; (iii) a device carrying energy that is [TRANSMITTABLE] to another device; (iv) a solid mass carrying a chemical that alters a state when said solid mass encounters a particular property in the [WELLBORE;] (v) a device carrying a [BIOLOGICAL] mass; (vi) a data recording device; [(VII)] a device that is adapted to take a mechanical action, and (viii) a [SELF-CHARGING] device due to interaction with the working fluid in the wellbore.

3. The method of claim 1, wherein said selecting the at [LEAST] one [FLOWABLE] device comprises selecting a device that provides a measure of a parameter of interest selected from a group consisting of: (i) pressure; (ii) temperature; (iii) flow rate; (iv) vibration ; (v) presence of a particular chemical in the [WELLBORE ; (VI)] viscosity; (vii) water saturation; (viii) composition of a material; (ix) corrosion; (x) [VELOCITY ;] (xi) a physical dimension; and (xi) deposition [OF A PARTICULAR] matter in a fluid.

4. The method of claim 1, wherein selecting at least one flowable device comprises selecting a device that comprises ; -a sensor for providing a measurement representative of a parameter of interest; -a memory for storing data relating at least in part to the parameter of interest; -a source of power for [SUPPLYING] power to a component of said [FLOWABLE] device; and -a controller for determining data to be carried by said memory. 5. The method according to claim 4 further comprising providing a transmitter for the at least one [FLOWABLE] device for effecting data exchange with the flowable device.

6. The method of claim 5, wherein effecting the data exchange comprises communicating with said at least one [FLOWABLE] device by a method selected from [A] group consisting [OF :] (i) [ELECTROMAGNETIC] radiation; (ii) optical signals; and (iii) acoustic signals.

7. The method of claim 1, wherein selecting the at [LEAST] one flowable device comprises selecting a flowable device that is adapted to carry data that is one of (i) [PRERECORDED] on the at [LEAST] one flowable device; (ii) recorded on the at [LEAST] one [FLOWABLE] device [DOWNHOLE;] (iii) self recorded by the at [LEAST] one [FLOWABLE] device; (iv) inferred by a change of a state associated with the at [LEAST] one [FLOWABLE] device.

8. The method of [CAIRN 1,] wherein selecting the at least one flowable comprises selecting a device from a group of devices consisting of: [(I)] a device that [ISFREETY] [MOVABLE] by the working fluid; (ii) a device that has variable buoyancy; (iii) a device that [INCLUDES] a propulsion mechanism that aids the at least one [FLOWABLE] device to flow within the working fluid; (iv) a device that is [MOVABLE] within by a superimposed field; and (v) a device whose movement in the working fluid is aided by the [GRAVITATIONAL] field.

9. The method of claim 1, wherein selecting the at [LEAST] one [FLOWABLE] device comprises selecting a device that is one of : (i) resistant to [WELLBORE] [TEMPERATURES;] (ii) resistant to [CHEMICALS ;] (iii) resistant to pressures in wellbores; (iv) vibration resistant; (v) impact resistant; (vi) resistant to electromagnetic radiation; (vii) resistant to [ELECTRICAL] noise; and (viii) resistant to nuclear fields.

10. The method of claim 1, wherein said introducing the at [LEAST] one [FLOWABLE] device into the working fluid further comprises delivering the at [LEAST] one flowable device to the working fluid by one of (i) an [ISOLATED] flow path; (ii) a chemical injection line; (iii) a tubing in a wellbore; (iv) a hydraulic line reaching the second location of interest and returning to the surface; (v) through a drill string carrying [DRILLING] fluid; (vi) through an annulus between a drill string and the wellbore; (vii) through a tubing disposed outside a drill string; and (viii) in a container that is adapted to release. said at least one flowable device in the [WELLBORE.]

11. The method of claim 1 further comprising [RECOVERING] said at least one [FLOWABLE] device. 12. The method of claim 14, wherein recovering the at [LEAST] one flowable device comprises recovering the at least one [FLOWABLE] device by one of (i) fluid to solid separation; and (ii) fluid to fluid separation.

13. The method of claim 1, wherein said introducing the at [LEAST] one flowable device [INCLUDES] introducing a plurality of flowable devices each such flowable device adapted to perform at [LEAST] one task.

14. The method of claim 13, wherein said introducing a plurality of [FLOWABLE] devices comprises one of (i) timed release; (ii) time independent release; (iii) on demand release; and (iv) event initiated release.

15. The method of claim 1, wherein introducing said at least one [FLOWABLE] device comprises delivering a [PLURALITY OF FLOWABLE] devices into fluid circulating in a [WELLBORE] to cause at [LEAST] a number of the flowable devices to remain in the wellbore at any given time, thereby forming a network of the flowable devices in the wellbore.

[15. THE METHOD OF CLAIM 15,] wherein the [FLOWABLE] devices in said [PLURALITY OF] devices are adapted to communicate information with other devices, thereby forming communication network in the [WELLBORE.]

17. The method of claim 1 further comprising providing a unique address to the at least one flowable device.

18. The method of claim 1 further comprising providing a data communication device in the

• [WELLBORE] for communicating with the at least one flowable device.

19. The method of claim 18 further comprising causing the data communication to exchange data with the at least one flowable device and to transmit a signal confirming said data exchange.

20. The method of claim 1, wherein said selecting said at least one flowable device comprises selecting the at least one [FLOWABLE] device that includes a sensor that is one of (i) mechanical (ii) electrical; (iii) chemical; (iv) [NUCLEAR;] and (v) biological.

21. The method of claim 1 further comprising implanting a plurality of spaced apart flowable devices in said [WELLBORE] during drilling of said [WELLBORE;]

[22.] The method of claim 7 further comprising receiving the data carried by said at [LEAST] one [FLOWABLE] device by a downhole device and transmitting a signal in response to said received signal to a device located outside said wellbore 23. The method according to claim 22 further comprising said device outside said [WELLBORE] at a location that is one of : (i) in a [LATERAL WELLBORE] associated with said [WELLBORE;] (ii) a separate [WELLBORE;] (iii) at the surface; and (iv) in an injection well.

24. A [WELLBORE] system utilizing at [LEAST] one [FLOWABLE] device constituting a data carrier that is adapted to be moved by a fluid flowing in the wellbore comprising : (a) a forward fluid flow path associated with the wellbore for moving the at least one [FLOWABLE] device from a first location of introduction of the at least one [FLOWABLE] device into the forward fluid path to a second location of interest; (b) a data exchange device at the second location of interest for effecting data exchange with the at least one flowable device that is one of (i) retrieving information carried by the at [LEAST] one flowable device ; or (ii) [INDUCING] selected information on the at [LEAST] one [FLOWABLE] device.

25. The wellbore system of claim 24 further comprising a return fluid flow path for moving the at [LEAST] one [FLOWABLE] device from the second location of interest to a return destination.

[26.] The wellbore system of claim 24, wherein the first location of introduction and the return destination are at the surface. 27. The wellbore system of claim 25, wherein the forward flow path is through a drill string utilized for [DRILLING] the wellbore and the return fluid flow path is an [ANNULUS] between the drill string and the wellbore.

28. The wellbore system of claim 25, wherein (i) the forward fluid flow path comprises a first section of a u-tube [EXTENDING] from the first location to the second location of interest and (ii) the return path comprises a second section of the u-tube returning to the return destination.

29. [THE WELLBORE] system of claim 24, wherein the second location of interest is in the [WELLBORE] and the data exchange [DEVICE IS LOCATED PROXIMATE] said second location of interest.

30. The wellbore system of claim 24 further comprising a controller for [PERFORMING] an operation that is one of (i) retrieving information from the at [LEAST] one flowable device

from the data exchange device, or (ii) causing the data exchange devices to induce a particular information onto the at least one flowable device.

31. The [WELLBORE] system of claim 25 further comprising a control unit for processing data contained in the flowable device returning to the destination.

32. The wellbore system of claim 30, wherein the [CONTROLLER PERFORMS] at [LEAST] one operation in response to the data [RETRIEVAL] from the at [LEAST] one flowable device.

33. A system for implanting at least one [FLOWABLE] device in the wall of the [WELLBORE] during drilling of the wellbore, comprising: [-A] drill string having a drill bit at end thereof for drilling the wellbore; -a source of drilling fluid for supplying the drilling fluid to the drill string; -a source for introducing at least one flowable device into the [DRILLING] fluid; and [-AN] implanting device [CARRIED] by the drill string uphole of the drill bit, said implanting device receiving the at [LEAST] one flowable device from the drilling fluid and implanting the at least one flowable device in the wall of the [WELLBORE].]

[34.] A method of utilizing [FLOWABLE] devices in a wellbore carrying a fluid from a [DOWNHOLE] location to the surface, each flowable device constituting a data carrier and adapted to be moved by the fluid, said method comprising: [-LOCATING] a plurality of flowable devices at a selected location in a [WELLBORE ;] and -selectively releasing the flowable devices into fluid, thereby moving the flowable devices carry data from the selected location in the [WELLBORE] to the surface.

35. The method of claim 34, wherein the locating of a plurality of the [FLOWABLE] devices [INCLUDES] locating said devices in a magazine from where said devices are individually [RELEASEABLE] into the flow of the fluid.

36. The method of claim 34 further comprising providing a [CONTROLLER] in the wellbore for inducing information n to the at flowable devices prior to their release into the fluid.

37. The method of claim 34, wherein the releasing the flowable devices [INCLUDES] at [LEAST] one of (i) releasing the [FLOWABLE] devices at predetermined [TIMEINTERVALS,] (ii) releasing a flowable device upon the occurrence of [I] particular event; or (iii) releasing the [FLOWABLE] devices periodically.

38. A discrete flowable device adapted [TOBEMOVEDATFEASTPARTIA) TYBYAF!UID] flowing in a wellbore, comprising: -a sensor for taking measurements relating to a wellbore parameter; -a [CONTROLLER] for processing the sensor measurements ; -a memory for storing data; -a power source for [SUPPLYING] power to elements of the flowable device; [-AN] antenna for communicating information to a device [EXTERNAL] to the [FLOWABLE] device; and a body housing the sensor, controller, memory and the power source, which body is adapted to protect the device from wellbore conditions.

39. The discrete [FLOWABLE] device according to claim 38 further comprising an external member that [INTERACTS] with fluid in the wellbore to aid in [GENERATING] electrical energy.

- 40. The discrete [FLOWABLE] device according to claim 39, wherein the [ELECTRICAL] energy is utilized to charge the power [SUPPLY.]
- 41. The discrete [FLOWABLE] device according to claim 38 further comprising a buoyancy device to alter the buoyancy of the discrete flowable device.
- 42. The discrete [FLOWABLE] device according to claim 38 further comprising a [PROPELLER] for aiding the discrete [FLOWABLE] device to flow in the wellbore.

Description Claims
